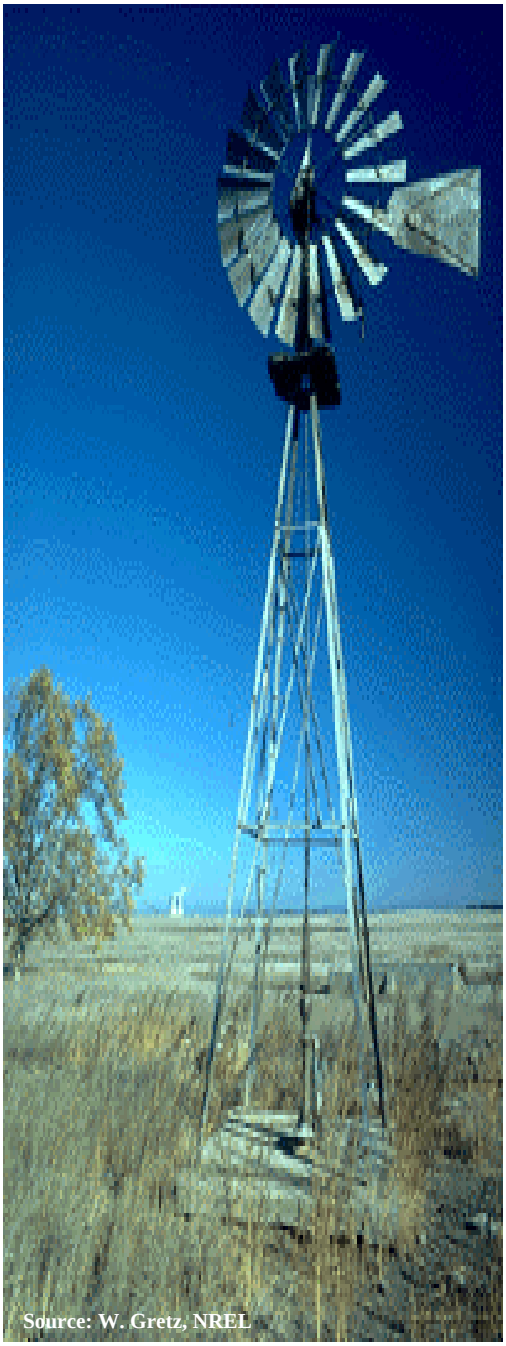
ENERGY PRODUCING SYSTEMS

WIND POWER

INTRODUCTION

The power of the wind has been captured by humans for thousands of years. Wind powered sailing vessels allowed us to cross entire oceans on a routine basis. Windmills have been used to grind grains or pump water since at least 200 B.C. In the early 1900s it was common place in the United States to see windmill towers throughout the Midwest. Most often these individual wind towers were used to pump water for livestock. Some windmill designs were used to generate electricity to operate lights and electric appliances in small rural homes. The construction of utility lines and the advent of fossil fuel use in the 1930s caused a rapid decline in the use of windmills in the United States.


Source: W. Gretz, NREL

Wind power is being rediscovered. Significant improvements in wind power technologies have occurred over the last several years. As a result of our steadily increasing energy needs, wind power is now an attractive prospect. Wind is a renewable energy source that can be utilized on a local basis throughout the world. Wind power systems decrease dependence on imported energy fuels and aid in establishing stable, long-term energy supplies. Over the last ten years, the global use of wind power has increased by 25 percent every year. Many projects are in service and other projects are underway to develop wind power in the United States. From 1998 to 2002, wind power has been the fastest growing portion of the electric industry in the United States.

WHAT CAUSES WIND?

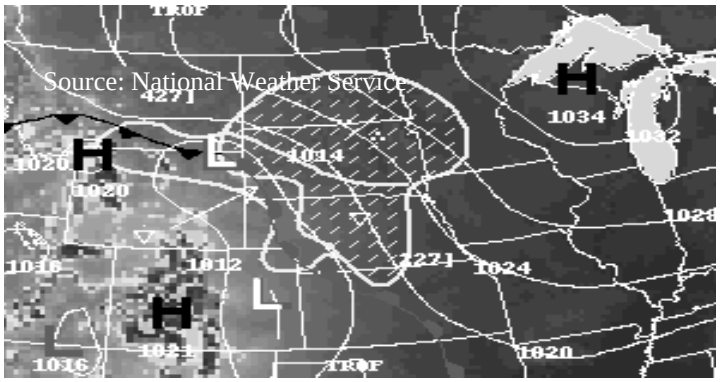
Wind is basically the movement of air over the earth's surface. These air movements are the result of interactions that occur between the sun's radiant energy, the surface of the planet and the atmosphere. A significant portion of the sun's energy is converted to thermal energy following absorption by the earth's surface. This absorption is not uniform and is highly dependent on the surface features of the planet. The surface of the earth varies dramatically, with large areas of water, desert, forests, mountains and grasslands. Each type of feature absorbs different amounts of the sun's energy. Additionally, the sun's rays are more direct in the equatorial regions than they are in Polar regions. As a result of these factors there is significant variation in the heating of our planet's surface.

Air masses poised above the earth's surface absorb a portion of the thermal energy associated with each location and this leads to variations in the temperature of the atmosphere from region to region. Warmer air masses tend to rise in the atmosphere as they gain in thermal energy. This warm air cools as it approaches the upper atmosphere and eventually sinks back towards the earth's surface. These air movements create the "flows" that we commonly think of as wind.

AIR PRESSURE

*When describing wind, meteorologists will often refer to areas of "high and low pressure", as represented on weather maps with an **H** (high pressure) and an **L** (low pressure). Air pressure is the force of the atmosphere on the earth's surface and it is related to the concentration of air molecules. The more air molecules present then the higher the pressure at the earth's surface. When a section of the atmosphere gains in thermal energy, the air molecules begin to gain in kinetic energy (movement) and separate from each other. The air mass expands and thus decreases its density (mass per volume) reducing the surface pressure on the earth.*

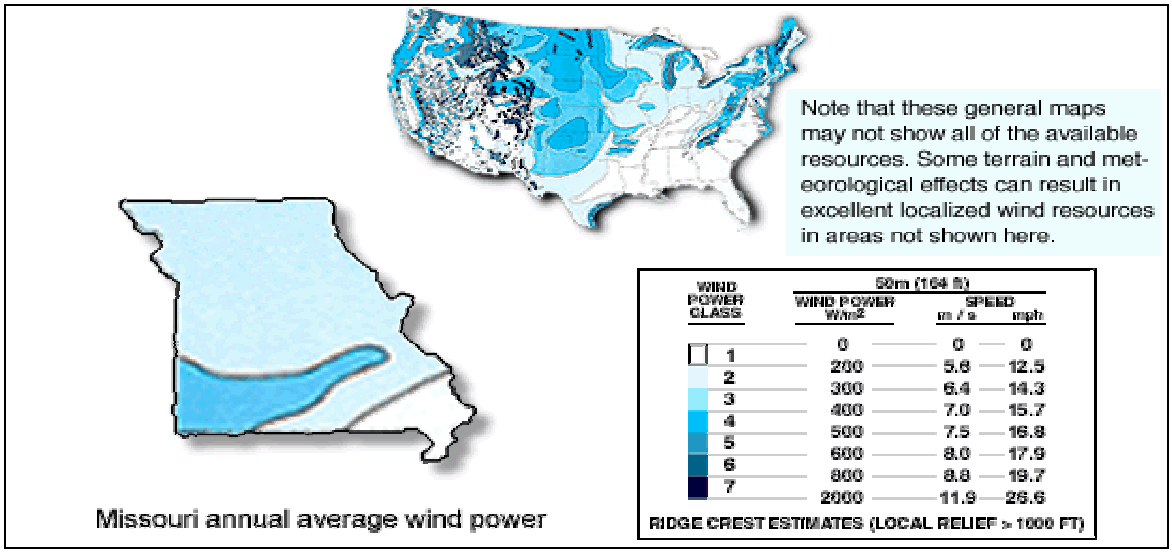
In general warmer air masses will yield lower-pressure systems while cooler air masses result in higher-pressure systems. Areas of <u>high</u> pressure (cooler air) will tend to flow towards areas of <u>low</u> pressure (warmer air), sort of like toothpaste being squeezed from a tube. This creates "flows" of air at the earth's surface and results in the formation of surface winds.



Such air movements are very common at the interface of land and water systems. The air over the land tends to warm up faster during the day, while the air over the ocean stays cooler. The resulting winds then tend to flow from the ocean (cooler: higher pressure) towards the land (warmer: lower pressure). This process reverses itself at night. The land rapidly looses its heat while the water retains its thermal energy and thus winds at night tend to flow from the now cooler land towards the warmer ocean air.

WHERE IS THE WIND?

The United States has substantial wind resources that could be harnessed to provide a significant portion of our nations electrical power needs. The development of these resources is in its infancy. Ninety percent of the wind energy resources exist in the Great Plains states where only minor development of wind power has occurred. Winds are typically characterized on a scale according to *power density* with **class 1** being the lowest and **class 7** being the highest. A class 4 or higher wind is usually required for large utility-scale power systems or so called "wind farms." This roughly corresponds to an average wind speed in excess of 15 miles per hour. States with high winds, listed in order of best potential are; North Dakota, Texas, Kansas, South Dakota and Montana. These so-called "wind states" have great wind power resources and in many ways represent the *Saudi Arabia* of American wind power. (See map below)



Source: ERIN, 1986 data. Recent maps estimating Missouri wind power opportunities are referenced below.

Missouri does have wind power potential. In fact, California does not have dramatically more wind than Missouri and yet the state of California has more wind power developed than any other state (2002 data: Energy Information Agency). Wind power in California has been promoted by attractive tax credits and power purchase agreements. A more recent map showing wind power possibilities for Missouri can be found at the end of this section. Additional information on wind power possibilities for Missouri are provided at the Missouri Department of Natural Resources web site:

http://www.dnr.mo.gov/energy/renewables/wind-energy.htm#maps.

The maps show several locations in Missouri that can expect utility grade wind class ratings of four. Much of the state can expect wind class ratings of three, allowing the use of wind towers to provide supplementary power to homes, run water pumps and bring electrical power to remote locations.

SPECIFIC CHARACTERISTICS OF WIND POWER

Wind power systems have several advantages over other energy sources. The wind is the product of natural global processes that are available worldwide. Wind is a renewable energy source and will not run out like fossil fuels, so investments in wind power can be made for the long term. Wind power systems are readily expandable by adding new towers to existing wind farms as energy demands grow. Wind farms do not dominate the land surface. The land below the towers can still be used for agricultural purposes, retaining the productivity of the land. Wind power is a clean source of power and operates without producing the air or water pollution associated with burning fossil fuels.

However, the wind does not blow all the time. Wind power systems are classified as intermittent power sources due to the occasional periods of minimal wind. In some locations the winds are far stronger during the day when the sun's energy is fueling the formation of wind. During the night winds can drop dramatically. The strength of the wind resource can change dramatically with the seasons.

HOW IS ENERGY GENERATED FROM THE WIND?

Historically wind power has been used to provide mechanical energy to propel boats, grind grain and to pump water. Modern wind power systems are predominantly used to convert wind to electrical power. This is accomplished in most cases by using a turbine system attached to a propeller-like blade. The turbine itself contains large magnetic coils and when they are rotated an electrical current is generated. Modern wind power systems look like large airplane propellers mounted on towers. Wind is used to force the propeller-like blades of the tower to rotate the attached turbine. The earth's friction slows surface winds down and so in general the higher the tower, the better the wind speeds.

One type of wind power system involves *wind farm*s designed to provide large quantities of power for use by municipal systems, cities and towns. These systems typically require a wind power rating of at least four or better. Site selection is a major consideration in terms of wind speed, proximity to customers and energy storage options such as pumped hydroelectric storage. Another type of wind power application involves smaller home-use systems. Such home or "village" systems do not require the strong winds required by utility systems and can be used to help offset home electrical needs in areas where wind power is moderate. These stand-alone units are especially appropriate for homes, farms or small communities that are located away from utility power line access.

The intermittent characteristics of wind power can be solved using energy storage systems. For example, hydro-based storage systems involve using the electricity generated during periods of high wind to pump water uphill to a large reservoir. The reservoir is then used as a conventional source of hydroelectric power during periods of low wind. Other systems have been designed that use the wind power to compress air in underground storage caverns. The high-pressure air is then in turn used to run turbines when wind availability is low.


Source: W. Gretz, NREL

Wind towers do have a visual impact and are not appropriate for installation in areas deemed to have a high aesthetic value. There have been issues in California with bird kills and wind towers. Studies have shown that this issue tends to be site specific and by carefully choosing a wind power site and using tower designs that do not promote bird roosting, these issues usually can be minimized.

The cost of capturing wind energy has dropped dramatically over the last 20 years. In locations with excellent wind resources, current state-of-the-art utility wind power plants now provide power for as low as 4 cents/kWh. Wind energy has become competitive with non-renewable energy systems currently used to generate electricity, such as coal or natural gas. Several very large wind farms are being planned or are currently under construction in Kansas, Texas, Washington, Oregon and California.

THE FUTURE OF WIND POWER IN MISSOURI

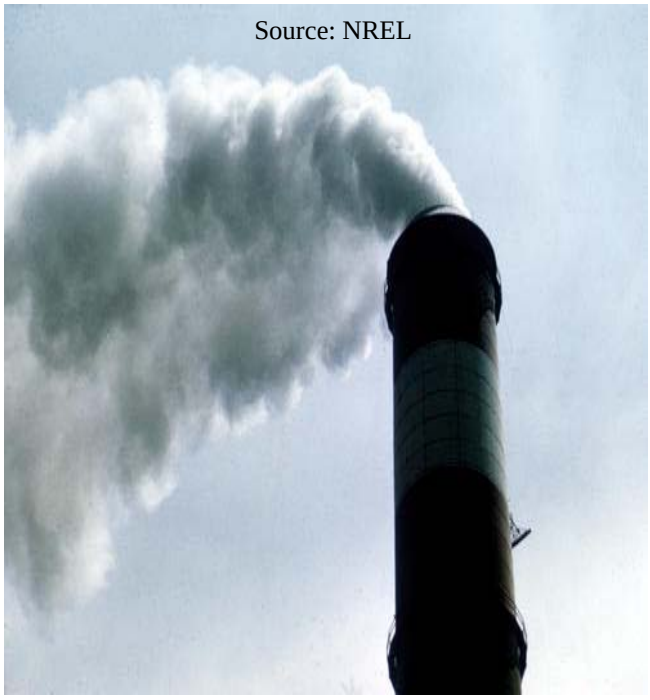
Wind systems are ideal when used in conjunction with other power sources. Wind power systems can serve as a preferred source of power and be "backed up" by conventional fossil fuel systems during times when winds

are low. This strategy can be used to reduce current levels of fossil fuel use and conserve this finite resource while reducing the associated environmental issues inherent with fossil fuel systems.


Source: W. Gretz, NREL

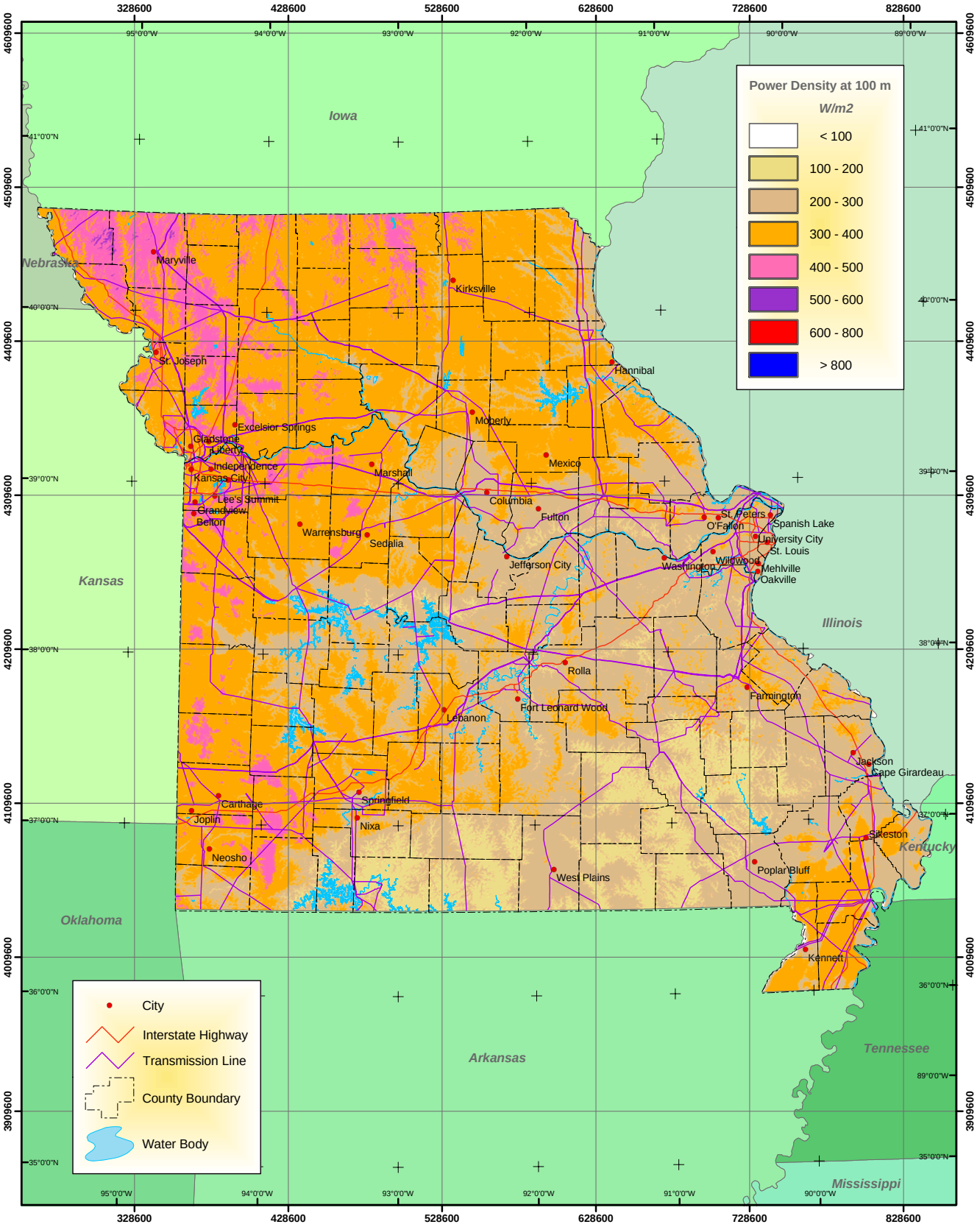
In 2002, the United States produced 52% of its electrical power needs by burning coal. In 1999 the state of Missouri derived 84% of electrical needs from burning coal. For Missouri almost all of this coal is imported from other states. Wind however, is available right here in Missouri. Development of wind power would enable Missouri to retain a portion of the dollars sent to other states to purchase coal. In 1997 Missouri spent more than 635 million dollars importing coal to the state. If even a small fraction of this money was spent on locally produced energy sources, such as wind power, the benefit to Missouri's economy could be significant.

Developing wind power along with other clean power systems would allow Missouri to burn significantly less coal. Missouri produces twice as much carbon dioxide as most of our neighboring states as a result of our higher state population and heavy reliance on coal. If we developed only 10 percent of the potential wind energy available in the United States we could reduce emissions of carbon dioxide by 30 percent according to the American Wind Energy Association.


Source: NREL

Wind Power Density of Missouri at 100 Meters

Interim Final Map



0 30 60 120 180 240 Kilometers

0 25 50 100 150 200 Miles

Missouri Department of Natural Resources

TrueWind Solutions

Projection: Transverse Mercator, Zone 15
Spatial Resolution of Wind Resource Data: 200m
This map was created by TrueWind Solutions using the MesoMap system and historical weather data. Although it is believed to represent an accurate overall picture of the wind energy resource, estimates at any location should be confirmed by measurement.

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